

# PC Measurement<sup>TM</sup> News

The Quarterly Newsletter of ComputerBoards, Inc.

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## Exploring the RTD



The RTD (or Resistance Temperature Detector) is actually a variable resistor with a resistance based on the device's temperature. The standard RTD is made of 99.99% pure platinum wire wrapped around a glass or ceramic core. (There are also thin film RTDs in which the platinum is actually deposited on a substrate.) Platinum has the major advantage of being very stable while being resistant to almost all types of external chemical degradation. Platinum RTDs are exceptionally stable, reliable, and long-lasting.

The transfer function of an RTD is referred to as its alpha. Alpha simply represents the relative change in resistance of the element per °C. The alpha units are actually ohms/ohm/°C. As is often the case, there are both American (alpha = 0.00392) and European (alpha = 0.00385) standards. However, unlike

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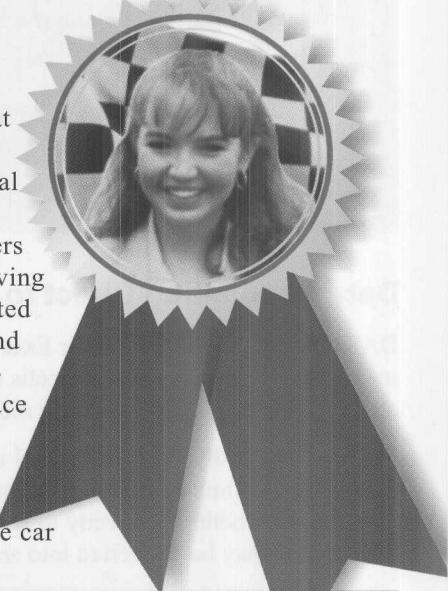
## Amy Morse Wins CBI 500!

Slotcar race at SAE Expo goes to Ohio engineering student.

by Bill Kennedy

Amy Morse, a sophomore engineering student at Cederville College in Ohio, took home the \$1000.00 grand prize for winning the first annual ComputerBoards CBI-500 slotcar competition during the 1998 Society of Automotive Engineers (SAE) Congress and Exposition in Detroit. Leaving behind a field of 410 other drivers, Amy exhibited superb concentration, hand-eye coordination, and road track savvy as she slipped past the second-place car by a mere 14/100<sup>th</sup> of a second. The race was set up and conducted by ComputerBoards, Inc., sharing booth space at the Expo with Hewlett-Packard. CBI and HP hardware and software were used for timing, scoring, and pace car control.

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## DAS Wizard<sup>TM</sup> writes data direct to Excel!

Call on the DAS-Wizard to fill your Excel worksheet with fresh data!

Excel is the most popular program for analyzing measurements, according to annual surveys of data acquisition board owners conducted by *Personal Engineering and Instrumentation News* magazine. Now there is a simple way to capture your important measurements directly to an Excel worksheet without programming. DAS-Wizard, an Excel add-in, automates the programming and operation of your DAS board. The data acquisition board is run and the data is gathered and inserted directly into your worksheet for immediate analysis and graphing. DAS-Wizard is so

easy to use we promise that you will be an expert in 20 minutes or less! On the next two pages is a tutorial which shows step by step everything you need to know to run DAS-Wizard and collect measurements into Excel.

DAS-Wizard-PRO is a great package for measurement professionals who want to customize Excel worksheets with GUI objects and write custom scripts with Visual Basic for Applications. DAS-Wizard-PRO includes the DAS-Wizard and the VIX-Components ActiveX controls. With ActiveX virtual instrumentation you can create beautiful, rich measurement environments within Excel!

DAS-Wizard comes complete ready to run every ComputerBoards data acquisition board. At only \$125 (USA) it is a "must have" even for experienced programmers. Simple, quick, accurate and fully integrated with your favorite program—Excel!

(See page 2)



;STEP 1 : Find the specific board.

```
mov dx, VENDOR_ID ; vendor id available from ComputerBoards
mov cx, PCI_DAS1602_DID ; device id available from ComputerBoards
mov si, 0
mov ah, PCI_FUNC_ID ;load pci function id into AH
mov al, FIND_PCI_DEV ;load search for device function into AL
int 1ah ;call bios ; Output: bl = device & function number
; bh = bus number
; CF set if error
```

;STEP 2 : Read the base address registers, using BX obtained earlier

```
mov di, BADR0_ADDR ;read base addr0
mov ah, PCI_FUNC_ID ;load PCI function id
mov al, READ_CONFIG_DWORD ;load read double word function
int 1ah ;call bios ; Output: ecx= register value, CF set on error
and cx, IO_ADDR_MASK
```

;At this point CX has the address contained in base address register 0. Repeat the above five instructions with the offsets of ;the other base address register in DI. You can store the contents of CX in some variable to avoid having to access the ;BIOS repeatedly.

; STEP 3 Find the interrupt used by the board.

```
mov di,INTLN_ADDR ;read the interrupt line reg
mov ah, PCI_FUNC_ID ;load PCI function id
mov al, READ_CONFIG_BYTE ;load read byte function
int 1ah ;bios interrupt call, returns ch zero, cl is IRQ#
```

;STEP 4 : Reset and enable interrupts if the board uses interrupts.

```
; First, copy base address 0 obtained earlier into DX
add dx, BMCSR_ADDR
OUTD BMCSR_DWORD ;reset mail box interrupts
sub dx, 4 ;dx=INTCSR_ADDR
OUTD INTCSR_DWORD ;reset pending interrupts and enable interrupts
```

The OUTD macro allows 32-bit I/O write to the Interrupt Control/Status register and Bus Master Control/Status Register. **CB**

*(RTD continued from page 1)*

many standards that continue to exist on parallel planes, the industry has largely now standardized on the European/DIN model with  $\alpha = 0.00385$ . Multiplying the RTD  $\alpha$  by its standard resistance at 0 °C provides a scale factor in ohms/°C. The typical unit is produced with a resistance of precisely 100 ohms at 0 °C, though there are Pt RTDs available with different base resistances. In the case of the standard 100 ohm, 0.00385, platinum RTD, the actual output scale factor is  $100 \times 0.00385$  or 0.385 ohm/°C

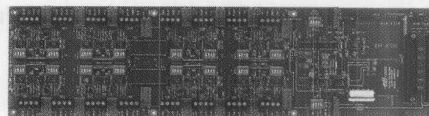
The transfer function of an RTD is not perfectly linear. In fact, the 0.00385 RTD scale factor varies from 0.44 ohm/°C at very low temperatures (-200 °C) to 0.29 ohm/°C at high temperatures (850 °C). There is a standard polynomial conversion formula that is easily implemented in software. However, for the typical system operating in the 0- to 100-°C range, simply using a straight 0.385 ohm/°C will provide better than  $\pm 1$  °C accuracy, and is often sufficient.

The RTD is the second most commonly used temperature measurement sensor. Only the thermocouple rates as more popular. When compared to the thermocouple, the RTD provides better inherent accuracy, has a more linear transfer function, provides almost as wide a temperature measurement

range, and avoids the problems of the cold-junction thermocouple. Thermocouple *system* error specifications typically fall in the range of  $\pm 3$  °C or  $\pm 5.4$  °F. Worst case RTD errors in the -50 to +50 °C range can typically be kept to under  $\pm 1$  °C, with repeatability of better than 0.1 °C.

The RTD also offers a larger output than the thermocouple. While the output of a J-type thermocouple is in the range of 50  $\mu\text{V}/^\circ\text{C}$ , a 100-ohm Pt RTD provided with a 1-mA excitation current has a scale factor almost ten times greater at 385  $\mu\text{V}/^\circ\text{C}$ . In a perfect world, this would make very little difference because you can simply increase the gain of your input system and obtain the same temperature resolution in either case. However, in the real, noisy world, the ability to run your RTD input gain at a factor of ten less than for a thermocouple makes the RTD system much more immune to ambient electronic noise.

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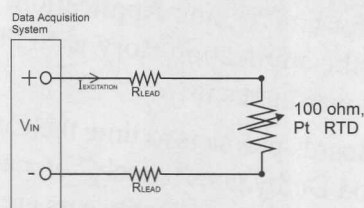


**ComputerBoards' CIO-EXP-RTD16 provides the signal conditioning required to connect up to 16 RTDs to any of our standard data acquisition boards.**

RTD is 0.1 milliwatt. Even smaller RTDs typically have self-heating coefficients in tenths of °C per milliwatt, so the self-heating effects are on the order of hundredths of °C, and can be ignored in systems using all but the tiniest of RTDs.

## LEAD RESISTANCE

The final disadvantage of the RTD is a bit more problematic and is depicted in the diagram below. Using a standard RTD with a standard resistance of 100 ohms, it is not always possible to ignore the resistance of the connecting wire. Thirty meters of 24-AWG connection wire represents approximately 2.57 ohms of lead resistance, which translates to over 6.4 °C of error. This error is often referred to as IR drop ( $I$  = current,  $R$  = resistance, and from Ohm's Law, the voltage drop equals current times resistance, or  $IR$ ).



*In a 2-wire RTD configuration, all current flowing through the RTD also flows through both connection leads. It is impossible for the input system to determine what part of the resistance measure is the RTD and what part is  $R_{LEAD}$ . Any resistance in the leads thus becomes an error source.*

In addition, the copper lead/connection wire has a temperature coefficient of approximately 3900 ppm/°C. (Since this specification is almost universally considered an error, it is stated as ppm/°C though it is identical to saying the copper has an  $\alpha=0.0039$ .) This creates a small error for short leads and small temperature fluctuations, but becomes significant with long leads and wide temperature ranges.

There are a number of ways to address the lead resistance error. These are discussed in the following paragraphs.

### 1. Ignore the lead resistance?

As much as we are all trained not to ignore known causes of errors, when an error is well defined, and known not to be significant to the measurement, it often makes sense to simply ignore it. This is often the case in RTD systems where the distance between the RTD and the measurement system is small. It's easy to calculate both the static error and temperature coefficient generated by the lead length.

$$\text{Static error (ohms)} = (\text{total lead length}) \times \text{resistance/length.}$$

It's important that you recognize that total lead length includes both lead wires, so if your RTD has 15 feet of lead wire between it and the measurement system, the total lead length is 30 feet. Typical resistances for a few common copper wire gages are shown below:

| Wire Size<br>AWG | Diameter<br>(Mils) | ohms /<br>1000' | ohms /<br>1000 meter |
|------------------|--------------------|-----------------|----------------------|
| 18               | 40.3               | 6.4             | 21                   |
| 20               | 32.0               | 10.1            | 33                   |
| 24               | 20.1               | 25.7            | 84                   |

Using the static error equation above and considering an RTD with 5-foot, 18-AWG leads (10 feet of actual lead wire), the resistance of the connections leads is  $10 \times 6.4 / 1000$  or approximately 0.064 ohm. At a standard 0.385 ohms/°C scale factor, the lead resistance represents an error of approximately 0.17 °C.

Even if the calculated static error is significant, it is often easy to remove during calibration. In particular, if the fully configured system is being calibrated based on ice baths or other temperature standards, the static lead resistance is removed and is not problematic. However, as we mentioned previously, the copper lead wires have a temperature coefficient with an  $\alpha = 0.0039$ . If the lead length is long and/or the lead temperature variation is small, it is also possible to ignore the effects of lead resistance. The formula for calculating the lead wire error coefficient is shown below. We've abbreviated the static error calculated earlier with the term SE.

$$\text{Temp co} = (\text{temp change}) \times 0.0039 \times \text{SE}$$

Let's look at a system with 60 meters of 24-AWG wire, subjected to a 15°C temperature change. First determine the static error or SE. Referring to the wire/resistance chart we see that 24 AWG wire has a lead resistance of 84 ohms per 1000 meters. Plugging into the SE equation:

$$\text{SE} = 60 \times 84/1000 = 5.04 \text{ ohms}$$

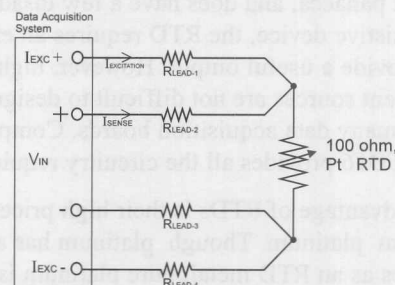
Now plugging the SE into the temperature coefficient equation

$$\text{Temp co} = 15 \times 0.0039 \times 5.04 = 0.295 \text{ ohms/°C}$$

Recalling that our system scale factor is 0.385 ohm/°C we see that in this example, the lead resistance temperature effects would induce a 0.77°C error in a 100-ohm Pt-based RTD system.

### 2. The 4-wire configuration

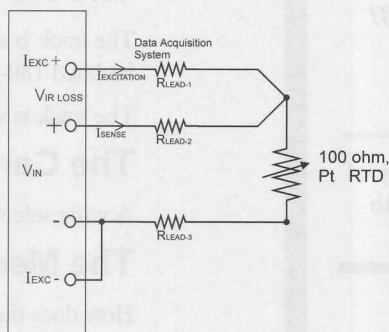
A simple and common method of eliminating lead wire effects in RTD systems is to use independent wires for excitation current and voltage measurement. The 4-wire configuration is shown below. Note that the voltage drops in excitation current leads are totally ignored by the measurement system, and because there is no current flowing in the measurement leads, lead resistance has no effect.



*In the 4-wire configuration, separate leads are used for the current excitation and the voltage measurement. All the current flows in leads 1 and 4, while the current in leads 2 and 3 is virtually zero. With lead 2 and 3 current zero, the measurement at  $V_{IN}$  is virtually unaffected by lead resistance or length!*

### 3. The 3-wire configuration

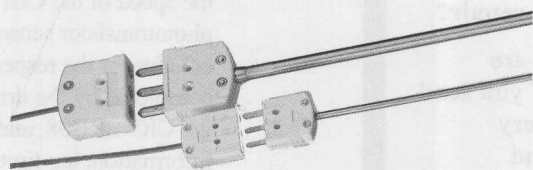
Perhaps the most common RTD configuration is the 3-wire. (All of the RTDs available from ComputerBoards, are 3-wire.) Though requiring somewhat more complicated input circuitry than the 4-wire, the savings of wire and connectors far outweighs the slight increase in input stage cost. In a 3-wire system, the error caused by the IR drop in the excitation current carrying lead is measured and removed. The actual method of removing the error is slightly more involved, because the system actually measures the IR drop in one of the leads and then subtracts it from the input. This simplification does require the use of identical wire for all connections, but this is rarely an obstacle. The block diagram of a 3-wire RTD system is shown below.



*In the 3-wire configuration, separate leads are used for the current excitation and the voltage measurement on one half of the RTD, while they are combined on the other. Since  $I_{SENSE}$  will be zero, there is no voltage drop across lead 2. The actual voltage drop in the current carrying lead is then measured at  $V_{IR\ LOSS}$ . Most systems then use analog hardware circuitry to remove the measured error from the input signal.*

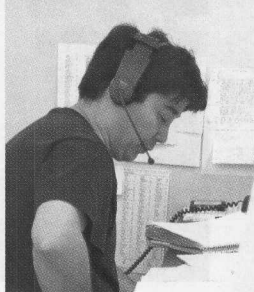
#### Conclusion:

Space prevents a more detailed discussion of the RTD than we have presented here. However, if you're looking for a highly accurate, stable and reliable temperature sensor, the RTD may be an ideal choice. If you have questions regarding any part of this article, or if you need help selecting the right temperature sensor for your application, we invite you to call one of our technical representatives, or e-mail your question to [tech@computerboards.com](mailto:tech@computerboards.com). We'll be happy to help you configure your system for optimum performance and a low price. **CB**



*In addition to selling the data acquisition interfaces, ComputerBoards now offers a wide variety of RTD probes and sensors!*

## "...the best in the industry."



ComputerBoards' TSSEs (technical sales support engineers) have earned a great reputation for being the "best in the industry." I've been watching them for over a month now, and I'm inclined to agree. These guys are a real class act. Even-tempered, bright, eager to serve, and uncommonly customer-considerate, they are truly dedicated to helping our customers, and every one a

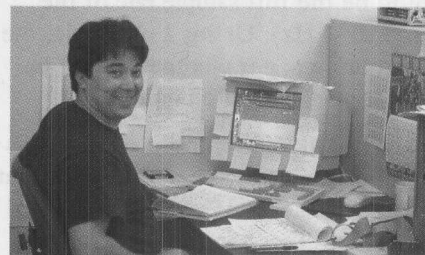
top-notch data acquisition professional. They all wear these wireless, remote, hands-free telephone headsets that allow them to walk around while they're talking to the customer. This way a TSSE can go look up a reference, pick up the actual board or boards the caller is asking about, go back to his workstation and create a duplicate environment, if necessary, without ever having to put the customer on hold. He can even go make a cup of coffee while continuing to answer the customer's questions.

The TSSE team is standing by to take your calls from 8:00 a.m. till 6:00 p.m., Monday through Thursday, and from 8:00 a.m. till 5:00 p.m. on Friday.

Over the next few editions of *PC Measurement News* we're going to profile some of our TSSEs so you can get to know the man behind the voice.

**Bob Vallee** is our feature TSSE for this edition. He has been with ComputerBoards for four years. He has been on the phones for about eleven months. He has an Associates degree in Electronic Engineering Technology from Massasoit Community College, has taken several courses in Visual Basic, and intends to return to take additional courses this summer.

Bob says he gets the most job satisfaction from the interaction he gets from the customers. When I asked him to what lengths he was willing to go to keep a customer happy, he said, "Whatever it takes. If I have the means to make the customer happy, I take it." It makes Bob's day when customers tell him things like, ComputerBoards gives the "best support in the industry," and "You saved my life today." Bob believes that if you treat your customers right and do your best to help them with all their questions, you can both go home at night feeling happier.



**Bob Vallee**, without headset, poses for the PCMN camera.

NOTE: During a routine telemarketing survey (today, while I was writing this profile), one of our customers said, "Bob Vallee was a wonderful person to work with...very nice, very thorough.... I am very happy with ComputerBoards." **CB**